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THE INSPECTOR-INSTRUMENT INTERFACE IN PORTABLE NDA INSTRUMENTATION

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Abstract

Recent electronics technology advances make it possible to design sophisticated instruments in small packages for convenient field implementation. This report describes an inspector-instrument interface design which allows communication of procedures, responses, and results between the instrument and user. The interface has been incorporated into new spent-fuel instrumentation and a battery-powered multichannel analyzer.

1. Introduction

A user, such as an IAEA inspector, uses several different types of instruments for his measurements. Obtaining good data and calculating results from a specific measurement are complicated by infrequent use of a particular instrument. This unfamiliarity increases the probability of making mistakes in operating the instrument or in calculating results. When the possibility for these errors is minimized, the user's main emphasis can be on performing the measurement and determining the meaning of the results instead of on deciding how to operate the equipment and calculate the results and uncertainties.

Sometimes the user performs a measurement in several places within a plant or in locations where the electrical main noise prevents the instrument from functioning properly. In these cases, a portable, battery operated instrument is required for measurement accuracy and ease. It is important that the instrument be designed so the size, weight, and ease of use are acceptable to the user.

A section of the Safeguards Assay Group at the Los Alamos National Laboratory has developed two microprocessor-based instruments to meet these needs. We are standardizing an inspector-instrument interface so that different instruments are operated in the same manner.

2. Goal

The goal of the interface development activities at Los Alamos is to provide an intelligent instrument "assistant" to the user. This assistant prompts the user through both operating and experimental procedures. It carries out programmed steps of a measurement, prompts for external information required, and then calculates results and provides an error estimate of the results. This type of instrument performs internal diagnostics and reports malfunctions to the user.

3. Philosophy

While the physical interface is not unique, it is important from the user standpoint to have the same well-defined philosophy of interaction for all instruments. Once the user learns this philosophy, he has a basic understanding of the operation of all the instruments that use the standard interface even if he has not used the instruments frequently or recently.

There are several important aspects to the interface philosophy. One aspect is that each valid user action has a uniquely defined result; i.e., the result of a legal key push is always the same and does not depend on the sequence of preceding key pushes. Along with the uniquely defined action, we believe it is important that each action be followed by a definite response. In some designs, a key push response is limited to tactile feel or an audible beep when the switch is made. Tactile feel is often misleading, however, and in high noise environments, the beep may not be heard. Therefore, our interface provides a visible response on the liquid crystal display (LCD) whenever a key is pushed.

It is important that the state of control is always known. At any time, the user should be able to determine the current function that is being executed by the instrument in a nondestructive manner, without losing information already acquired or aborting an action in progress.

Prompts to the user should always present the possible responses. For example, if the instrument is asking for a gain set point, the display should show the range:

```
GAIN= 40
GAINS (1-1024)
```

Proper interface design defines which actions are valid at all stages of control. The instrument must prevent actions that are not valid at any particular time, and furthermore, it must recover from an invalid action request with minimal inconvenience to the inspector. For example, dumping multichannel spectrum data to tape while the unit is acquiring data is an invalid procedure. If a save-to-tape action is requested while spectral data acquisition is occurring, the instrument responds with INVALID ACTION REQUESTED and continues to acquire data, ignoring the request to dump the data to tape. To store the spectral data to tape, the user halts the data acquisition and then requests the data dump. This enables the instrument to write a consistent set of data to the tape along with the actual elapsed time.

The instrument should be able to record raw data which it has acquired, along with the critical parameters such as high voltage, discriminator settings, count time, etc. The instrument should do this automatically to save user time and reduce the chances of logging an incorrect value. The instrument must have the hardware capability to set or read the set point of the parameter to be logged.

A measurement log should uniquely define a measurement. The time and date are necessary and may be supplemented with other information such as inspector, facility, and sample IDs.

4. Evolution

ION-1

The first instrument designed during the development of the standard interface was an ion- or neutron-detector electronics package (ION-1)[1] used in spent-fuel measurements. It measures the relative gamma dose when used with a gas-filled ion chamber. Its current sensitivity is from 0.1 pA to 637 nA. The actual gamma dose is a function of the detector. Neutrons are counted when pulses exceed a lower-level discriminator (LLD) set by the instrument. The instrument automatically sets the optimum gain for the gamma channel and can set the LLD automatically for a ^{235}U fission chamber. All calculations are done internally using a 24 bit $10^{\pm 38}$ mathematics package which performs addition, subtraction, multiplication, division, and calculates the square root.

A photo of the electronics package is shown in Fig. 1. On the front panel are the power switch, ASCII character display, and keypads. On the rear panel (not shown) are the ion chamber input, connector-to-supply high voltage to the fission chamber, connector for the fission chamber preamplifier power, fission chamber input, battery charger input, and RS232 serial interface connector. All rear panel connectors are different to prevent misconnection. An overview of the instrument operation is presented here; Ref. 1 contains more detail.

The physical interface is the front panel, which consists of an LCD with two rows of 16 ASCII characters to convey instructions, results, and options to the user; a 4 by 4 information entry and command keypad, and a 1 by 4 control keypad. The keypad labels are shown in Fig. 2. Some entry keys have both lower-case entries and upper-case commands, like a hand-held calculator. The most frequently used keys, such as the digits 0-9 and scroll lines ↑ and ↓, were chosen as lower-case keys. The upper-case keys contain the functions the instrument can perform. The lower-case entries are used by simply pushing the keys. The upper-case commands are accented in yellow to emphasize that the yellow control key, SHFT, must be pushed to access a yellow upper-case command.

In addition to SHFT, there are three other keys on the control pad. The ENTR key registers an entered number. That is, the instrument displays the number as it is typed; it does not use the number until ENTR is pushed.

The END key signals the instrument that the present function command is no longer needed. The instrument ends the function, displays a standard message requesting another action, the waits for the next function. The END key can also be pushed to abort a function at any time. For example, if during a 15-min acquire, the user needs to make a detector placement change, he pushes END, repositions the detector, and then pushes ACQ.

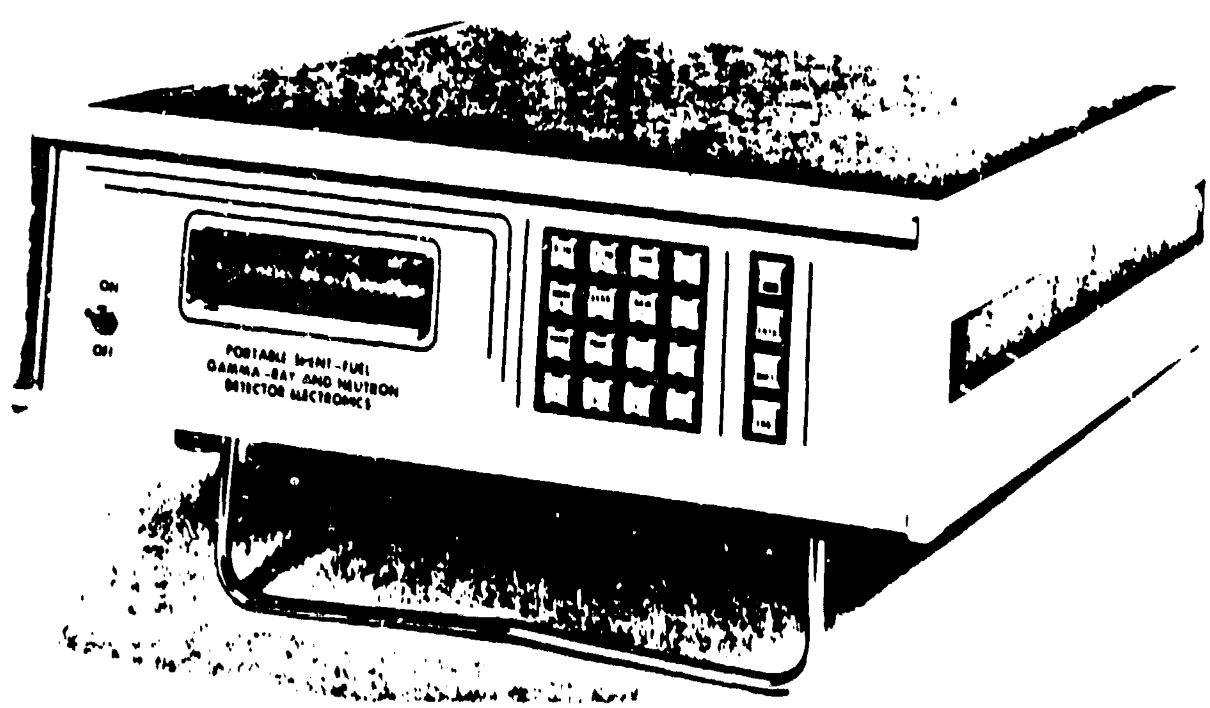

Fig. 1 ION-1 electronics package

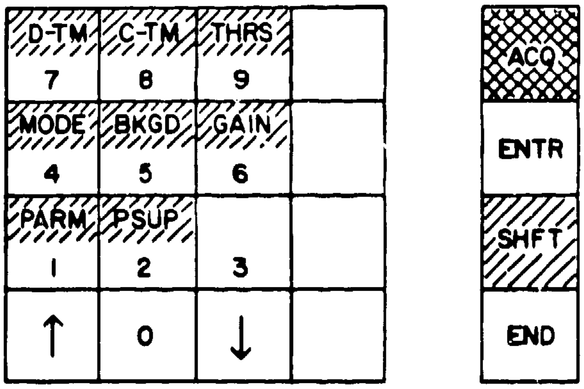

Fig. 2 ION-1 keypad labels

The final key on the control pad is ACQ, which is really a function (Acquire). Because this key is frequently used, it is given preferred status by placing it at the top of the control pad and giving it a special green background color. The command causes data to be accumulated.

During any input sequence, only certain key pushes are valid. If an invalid key is pushed, the LCD contains:

```
INVALID ENTRY
PUSH VALID KEY
```

for one second. After one second, the display on the LCD returns to the display that was present immediately before the invalid key push. The user can then proceed as if he had not pushed the invalid key.

A brief description of the functions is given in Table I. While the number of available functions may seem confusing, a standard measurement is simply initiated by pressing the green ACQ key. After pushing the ACQ key, the user is prompted through each step and option in the measurement. At measurement completion, the final results with background subtracted and error estimates are presented to the user in this form:

```
1252  81-03-26   ↑
G = .0156±.0010  ↕
N = 1270.0±25.6  ↕
IN 100 SEC       ↓
```

There are four lines to the results display page. Only two lines are visible on the LCD through the display window at any one time. The window can be moved up and down along the page using the ↑ or ↓ keys. The arrow indicator in the lower right-hand corner of the window tells the user which keys are valid to push to find more information.

In a sense, the instrument is a "one-key" instrument. The user need only remember to push a single key to acquire data; after this, the user responds to the instrument. The other keys add much versatility to the unit with minimal confusion.

To demonstrate the user-instrument interaction in entering information, a sample procedure to set the time and date is described. Pushing SHFT and then D-TM produces this display:

```
(Field 1)      (2)   (3)   (4)
0000 HRS        0  -  1 -  1
ENTER TIME
```

The fields are labeled for clarity. They are:

Field 1 - time in 24 hour format,
Field 2 - year,
Field 3 - month,
Field 4 - day.

A blinking cursor, denoted by an underscore, appears whenever a response is needed; it is located at the left-most digit in Field 1. To enter 3:25 p.m. on March 26, 1981, follow these steps:

Type 1525. The digits are displayed as they are entered and the cursor moves one position to the right until the last digit in the field is entered. Push ENTR and the cursor moves to the first position of Field 2. Type 81 and push ENTR; the cursor moves to Field 3. Type 3 and push ENTR; the cursor moves to Field 4. Type 26 and push ENTR. The cursor now returns to the leftmost digit of Field 1. The display is now:

```
1525 HRS  81-03-26
ENTER TIME
```

If ENTR is pushed again, the display remains the same except that the cursor is moved to Field 2. Changes can be made in any field by moving the cursor to that field and entering the new number. When the display is correct, the END key is pushed to end the function.

When decisions are to be made, the instrument presents the possible choices. An example is the mode function which allows the user to select which type(s) of data are to be collected. The sequence SHFT, MODE brings the following message:

TABLE I
ION-1 Command Table

With all commands except ACQ, the SHFT key must be pushed first.

ACQ:	Initiate data accumulation.
D-TM:	Set date and time. Default values are 0000 hours, day 1 of month 1 of year 0.
C-TM:	Set neutron accumulation time. Default value is 200 s.
THRS:	Set the lower-level discriminator of the neutron channel. Default value is 50.
MODE:	Select data accumulation mode, neutrons only, γ only, or both. Default value is both.
BGND:	Take background in selected mode.
GAIN:	Select manual or automatic gain adjustment. Default value is automatic adjustment.
PARM:	Informational display showing currently selected parameters.
PSUP:	Informational display showing power supply status.

GAMMAS=0 BOTH=2
NEUTRONS=1 OPT=2

The blinking cursor indicates the unit is awaiting a response. A 2 is defaulted as an input. 0 or 1 may be entered. When the desired choice is displayed, push ENTR.

MCA

The second instrument in which this interface was implemented is a portable, 1000-channel multichannel analyzer (MCA).[2] The MCA is an extension of an MCA unit demonstrated by another group at Los Alamos.[3] The analyzer has built-in amplifiers for NaI and high resolution detectors. Other features include a cathode ray tube (CRT) display with cursor, region-of-interest assignment with area or integral readout, a livetime clock timer, adjustable upper- and lower-level discriminators, magnetic tape storage, and serial output data dump. The operating system for the MCA was built on the system designed for ION-1. Because of front panel constraints on the initial design, only a 4 by 4 keypad was implemented as seen in Fig. 3. The LCD display is again two lines of 16 characters. A CRT was necessary to display the spectra. While we strive for standardization, changing the CRT vertical scale via the keypad was deemed too inconvenient as opposed to using a rotary knob. Therefore, the communication from the operator to the instrument uses the keypad and the vertical scale knob. There is no hardware connection between the vertical scale knob and the CRT display; the control is accomplished through software.

The implemented commands are given in Table II. Any integer number can be entered by digit entry as in ION-1 or, additionally, by using the INC or DEC key to increment or decrement the number in the field which contains the LCD cursor. Pushing a key for more than one-half of a second causes the number to continuously increment or decrement at an accelerating speed. Because of the limited number of control keys,

TABLE II
MCA Command Table

With all commands except data acquisition (STRT), the SHFT key must be pushed first.

- STRT: Acquire data.
- STAT: Examine or change instrument parameters.
- CALC: Compute count sums or areas of assigned regions.
- ROI: Assign or change regions of interest.
- ENRH: Perform ^{235}U enrichment measurement.
- DUMP: Write current spectrum to serial port.
- TAPE: Read/write spectra to tape, position tape or erase tape.

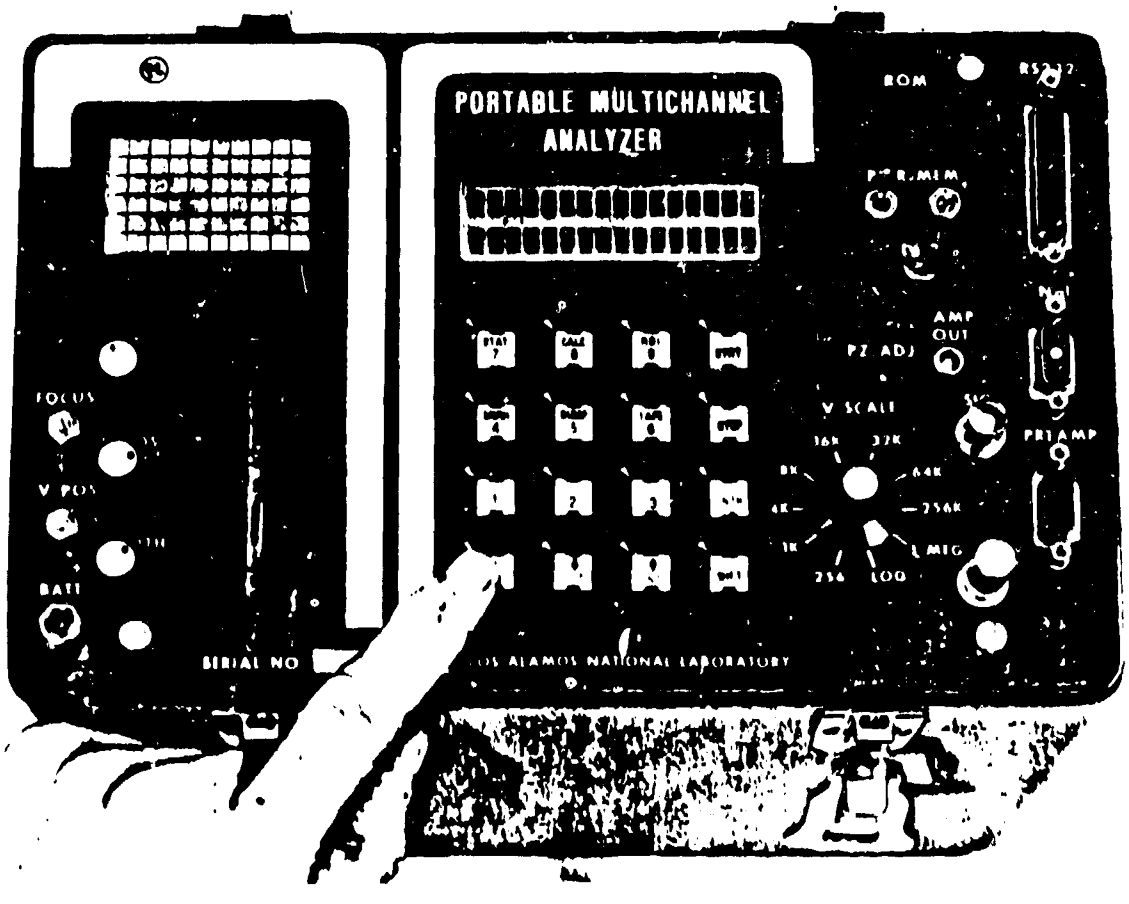

Fig. 3 Portable MCA

TABLE III

```
CT TIME= 100 S
E TIME=       S

RATE=        C/S
DEAD TIME=   %

DETECTOR=1
NAI=1 GER=0

INPUT POLARITY=0
POS=1 NEG=0

GAIN=8
GAINS 2,4,8,16

SET HV= 0
HV (0-4095)

LLD=10 (0-255)
ULD=255 (0-255)

MGRP=1 OF 1

BATT=15.00
+ 5= 5.00

+12= 12.00
-12=-12.00
```

more extensive use of display pages was made. For example, the status function is used to read or set all parameters in the MCA. This is illustrated by Table III. Recall that in ION-1, detector type, threshold, and count time were all set by different functions.

While the same basic mathematics package is used in both instruments, floating point entry of variables was required by the MCA. Since there is no logical increment with a floating point number, the INC and DEC keys become illegal keys during floating point entry.

The CRT is a self-refreshing display with 256 vertical x 1024 horizontal resolution. It has a single cursor controlled by a software register which is changed using the integer entry routine only when the cursor channel number is displayed on the screen in conjunction with the blinking cursor. The vertical scale knob is read constantly except during tape functions.

The tape function can seek the beginning of a tape, erase a tape, write a data file to tape, read a file from tape, and view the parameters stored along with the data last read from the tape. Further details are found in Ref. 2; measurement logging using the tape will be enhanced to fill the needs of the IAEA.

The first automated measurement implemented is a ^{235}U enrichment measurement.[4] The user must remember only to push the ENRH key to start the instrument stepping through the measurement procedure. The user is given the option of entering or measuring the necessary calibration constants (A and B) and is prompted through the entry or calibration procedures, and then through the measurement procedures. All calculations are performed by the instrument and the results along with uncertainties are reported with 7-digit precision.

The following example demonstrates an enrichment measurement where the calibration constants are entered. Push SHFT, ENRH to begin the measurement. The message

```
MEAS=0, ENTR AB=1
DETERM AB=2, DO=0
```

on the LCD presents the measurement options:
ENTR AB—to enter values for constants A and B,
DETERM AB—to determine these constants by measuring standards, or
MEAS—to retain constants which were established in a previous measurement and proceed to measure an unknown.

The measure option is defaulted and the blinking cursor indicates that a user response is necessary. To choose the enter constants option, type 1, then ENTR. The prompt for defining region of interest appears next:

```
SET WINDOWS=0
PRESET=1  DO=1
```

One can select option 0 to manually set the windows. The resident ROI command is invoked to accomplish this. If option 1 is selected, the windows and gain are preset to predefined values without further user interaction. To register this choice, press ENTR. After the windows and gain are set, the LCD contains:

```
A= 4.499E-02
B=-3.956E-02 ↓
```

where A and B are the previously established values (they are set to 0 at power up). Use the digit keys and ENTR to enter the desired values. When the correct values are entered, push SHFT, ↓ to continue to the next display which shows the count time:

```
CT TIME = 100 S ↓
```

Make any needed changes and continue to the next step by pushing SHFT, ↓. The display directs the user to:

```
PREPARE UNKNOWN
PUSH STRT
```

When the sample is properly positioned, push STRT; the memory is erased and data acquisition begins. During acquisition, an approximate enrichment is calculated, and the display, which contains the enrichment, time remaining, and count rate, is continuously updated. When count time is complete, the following summary page is available to the user:

```
W1= 215 TO 313
W2= 323 TO 421 ↓
E TIME= 500S
GAIN= 8          ↕
Σ1= 96935
   ±311.4        ↕
Σ2= 37969
   ±194.9        ↕
A= 3.499E-02
B=-4.956E-02     ↕
E= 3.02±.0101
NEXT RDY?, STRT↑
```

The LCD window is placed as shown by the dashes. To view the other information one must use the ↑ or ↓ keys. To make another measurement, push STRT. As with any of the functions, push STOP to end the function. It should be emphasized, the user need only remember to invoke the ENRH command to gain the assistance of the instrument in making the enrichment measurement. After all parameters are set, the enrichment measurement of an unknown is made by simply pushing STRT.

5. Anticipated Future Additions

During the development of the MCA, we found that some additional keys may be necessary. A possible design for our next iteration is shown in Fig. 4.

Another control key labeled NEXT should be added. This key would allow the user to manually move from the currently displayed page to the next page in a function. (At present, the user advances by responding to a question.) The NEXT key would allow the user to signal that all actions on the currently displayed page are complete.

To allow for alphanumeric input, the INC and DEC keys will be used. When an alphanumeric field is active, pushing the INC key will cause the entry character to scroll from 0-9, then A-Z. When the proper character is displayed, press ENTR to register the character and move the cursor to the next position.

Consideration must also be given to a more general floating point number entry scheme. A change-sign key may be necessary, and a decimal point and enter exponent may be desirable.

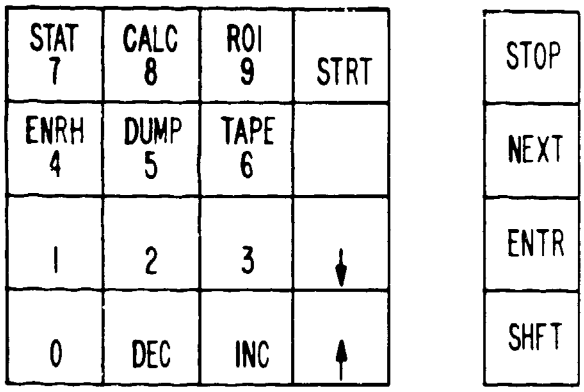

Fig. 4 Possible MCA keypad labels

6. References

1. J. K. Halbig and S. F. Klosterbuer, "Portable Spent-Fuel Gamma-Ray and Neutron Detector Electronics User Manual," to be published as LA-8707-M.
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4. L. A. Kull and R. O. Ginaven, "Guidelines for Gamma Spectroscopy Measurements of ^{235}U Enrichment," Brookhaven National Laboratory report BNL-50414, March 1974.